OXC-8854
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29 December 1961

MEMORANDUM FOR THE RECORD

SUBJECT : Hydraulic Pump - JT11D-20 Engine

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REFERENCE: Memorandum for the Record from [redacted] dated 21 December 1961, Subject: Brief Status Report on OXCART - Western Suppliers and Operations. (OXC-8834)

1. The purpose of this report is to update Headquarters information concerning subject pump prior to 4 January 1962 in order to clarify and expand upon certain points of interest raised on 20 December 1961.

2. Lockheed/Pratt and Whitney Pump Similarity:

a. As far as can be determined short of comparative drawing examination, with the exception of some material changes, the major physical difference between the Lockheed and Pratt and Whitney pump is displacement as determined by length of stroke. The Lockheed pump has a displacement of 2.5 cubic inches while the Pratt and Whitney pump has a displacement of 2.69 cubic inches. As with piston engines, displacement is the basic factor in sizing a piston pump relative to a required output capacity. Like automotive engines, a pump with a different displacement becomes in effect a different pump even though all other physical properties are identical. With this increased displacement and without increased pressures, it should not be said that the Pratt and Whitney pump on the basis of higher speed and flow rate alone is overloaded. If the higher flow rate were achieved by increased speed alone and accompanied by increased pressures, without benefit of increased displacement, then it might be said that the pump is overloaded.

b. It certainly can be said that the Pratt and Whitney pump is subjected to more severe operating conditions than the Lockheed pump. Greater fluid and environmental temperatures, lack of lubricity and increased steady state (off-demand) output requirements which dictate a continuous flow of 12 gallons per minute for cooling contribute to this duress.

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3. Primary Pratt and Whitney Pump Specification Requirements:

a. Primary specification requirements are listed herewith:

Output pressure (psi)	3000 max.
Flow (gallons per minute)	53 max.
Flow - steady state continuous (gpm)	12
Speed (rpm)	5000
Fuel temperature (°F)	-65 to +400
Ambient temperature (°F)	-65 to +1125

The above temperatures are specification limits and not necessarily reflective of M3.2 operation. Current testing for M3.2 conditions calls for 850°F ambient temperature and 350° fuel temperature.

The above values for flow and speed may be compared with the Lockheed requirements of 46 gpm and 4600 rpm as listed in referenced memorandum. Lockheed temperature values are unknown to the writer but are believed to be considerably less than those of Pratt and Whitney. Lockheed pressure is understood to be 3000 psi.

b. The above specification parameters with particular emphasis on the 53 gpm maximum on-demand flow are based primarily upon nozzle response time requirements relative to airframe inlet matching. If the flow were reduced to 46 gpm as suggested by referenced memorandum, the engine exhaust nozzle as governed by airframe inlet conditions via the main fuel and exhaust nozzle controls would not respond to changed inlet conditions quickly enough to prevent incompatibility with the possibility of shock expulsion. Fast response is also important for bleed bypass activation in order to prevent surge during cycle transition.

4. TCP (tricresyl phosphate) Additive for Lubricity: Neither Pratt and Whitney nor [redacted] have tested the hydraulic pump using TCP in order to improve lubricity for the following reasons: 25X1A

a. Thermal stability: Tests were conducted by Pratt and Whitney during August in order to evaluate the effect of TCP on PWA-523 fuel stability. Results indicated that 0.5% TCP concentration reduced fuel thermal stability from a coker code 2 (maximum allowable per spec.) to code 6 which is tantamount to JP-4 and not acceptable for control and fuel nozzle operation.

b. Introduction of 1% TCP to fuel going to the hydraulic pump as suggested by referenced memorandum has been considered but then discarded because of the added weight and complexity of an additional

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system required to store, meter, and cool the additive and because pump discharge fuel is not controlled or contained in a completely closed loop due to cooling requirements. Fuel is continuously discharged by the pump during steady state or off-demand conditions at the rate of 12 gallons per minute for cooling purposes. This 12 gpm which is equivalent to 4320 pounds per hour is continuously recirculated through the hydraulic and the engine fuel system and finds its way to thermal stability sensitive components such as controls and fuel nozzles via five major channels:

(1) Directly to the afterburner fuel control and spray-bar nozzles during partial or full afterburning.

(2) Direct return to airframe tanks via afterburner fuel control junction during non afterburning.

(3) Direct return to airframe tanks via windmill bypass valve junction during all engine operation.

(4) Recirculation to main fuel control and main fuel nozzles via main fuel pump interstage and chemical ignition unit cooling jacket during all operation.

(5) Recirculation to main fuel control and main fuel nozzles via main fuel pump inlet and exhaust nozzle control during all operation.

Approximately 40% of the 4320 pounds per hour hydraulic pump discharge is recirculated through the main control and nozzles as described in items (4) and (5) above. The balance is divided between afterburning and tank return as described in items (1), (2), and (3) above and in recirculation through the hydraulic pump itself.

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In addition to the above factors bearing on the use of TCP in the engine hydraulic system, fuel thermal stability tests were conducted by Lockheed during August, the results of which were summarized by Mr. C. L. Johnson in a letter to [redacted] dated 22 August 1961 as follows: "It is apparent from the enclosed data that using the same anti-wear additives (TCP) in the fuel that we use in our hydraulic oil is probably not the answer to your [redacted] fuel pump problem; but using this anti-wear approach to make a [redacted] fuel pump work may still be valid if additives that do not unduly deteriorate fuel properties can be found." The Pratt and Whitney search for a suitable additive implemented prior to August 1961 has so far been non-productive. According to [redacted] this approach has been exhausted.

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5. Fatty Acid Treatment for Lubricity: A dry film treatment utilizing fatty acid has been applied to cylinder block bores and to the valve plate face producing a nitride like hardened lubricous surface. Sea level testing to date of [redacted] has revealed some improvement. The first pump incorporating this treatment is now enroute to Pratt and Whitney where mission cycle bench evaluation will be made.

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6. Test Method and Current Results:

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a. Endurance testing at [redacted] as specified by Pratt and Whitney follows a mission type of temperature cycling. In general, this mission cycle progresses in incremental time periods with increasing fuel temperatures up to 220°F fuel temperature. From this point on time increments are reduced to 10 minutes each with 20° fuel temperature increments and with increasing ambient temperature until fuel temperature reaches 350°F with an ambient of 650°F. This point is held for 10 minutes followed by "cool down" to 150°F. This single cycle which consumes 3 hours is then repeated with periodic inspections.

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b. Very current reports from [redacted] to Pratt and Whitney describing test results reveal the following:

(1) 16 consecutive hours (4 cycles) of mission temperature cycling has been completed on one pump without undue wear. The same pump after this inspection was then cycled to 23 hours. Inspection here revealed .003 inch piston to bore wear. This pump incorporates nitride hardened bores and tungsten carbide bearing seats but without the fatty acid treatment.

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(2) 75 hours of continuous operation at a fuel temperature of 200°F on one pump has been completed.

The above results reflect substantial improvement within the last two weeks. To date these results have not been confirmed by engine test evaluation.

7. <u>Alternate Sources</u>: Pratt and Whitney investigation of possible alternate sources which include [redacted] and [redacted] has revealed no other pump experience or development compatible with the Mach 3 environmental requirements. An alternate supplier selected now would start development at the point where [redacted] was about two years ago and then would probably replow the same long hard furrow.

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8. <u>Centrifugal Design</u>:

a. Justification for pursuit of this somewhat controversial and admittedly unconventional centrifugal concept as cited by [redacted] revolves around the following factors:

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(1) The present D-20 engine afterburner single stage centrifugal fuel pump developed by Pratt and Whitney has been successfully tested to 1500 psi.

(2) The present RL-10 rocket engine single stage centrifugal fuel pump developed by Pratt and Whitney has been successfully tested to 2000 psi.

(3) A centrifugal pump will not produce the pulsating flow currently experienced with the piston pump which is believed the key factor involved in the hydraulic system flow dynamics problem.

(4) A centrifugal design by being centrifugal and by permitting the use of oil lubricated bearings should greatly reduce the lubricity problems now encountered with the piston pump.

b. Certainly this centrifugal design involves disadvantages. Some of the more obvious are:

(1) Inherently lower pump efficiency. This means more losses through the pump. More losses mean more heat rejection to the fuel.

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(2) High pressures required will certainly present thrust balance and stage sealing problems.

(3) Inherent difficulty involved in attaining lower than maximum flow rates such as is required during steady state or off-demand conditions with a fast enough response necessary to satisfy sudden on-demand requirements.

In spite of an approximate 18 month lead time and in view of the lack of any other appropriate piston pump development program, it would appear that the pursuit of this centrifugal design for a long range production back-up is not without some merit.

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Development Branch
DPD-DD/P

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